Biological Evaluation of Gypsy Moth Populations

On the Allegheny National Forest, 2013

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Photos on cover: Gypsy moth defoliation Allegheny Reservoir, June 15th, 2013.

ABSTRACT

During the spring of 2013, the Allegheny National Forest (ANF) experienced an outbreak of the gypsy moth, a non-native defoliator of forest, shade and ornamental trees. Forest Disturbance Mapper data from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET) detected ~ 105,000 acres of detectable change during this time. Field personnel reported widespread re-foliation of trees in the defoliated areas. Personnel from the USDA Forest Service, Northeastern Area, Forest Health Protection, Morgantown Field Office along with ANF personnel conducted gypsy moth egg mass surveys at 35 areas across the ANF. The purpose of these surveys was to estimate gypsy moth population densities through fall egg mass counts, and to assess the need for treatment in 2014. Average egg mass densities ranged from 0-1,020 egg masses/acre. Although extensive gypsy moth larva mortality was noted in all areas surveyed; three of the survey areas, Cornplanter Bay, Hodge Bay and Hopewell campground contain egg mass densities sufficient to predict localized moderate to heavy defoliation in 2014. Light defoliation is predicted at Sugar Bay and Central Hodge Bay with the remaining thirty areas having egg mass densities sufficient to predict background or nuisance levels of gypsy moth defoliation.

Purpose and Need

The Morgantown Field Office (MFO) received a request from Andrea Hille, Forest Silviculturist, with the Allegheny National Forest (ANF), whose staff observed gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae) defoliation across the ANF. This evaluation was undertaken by the MFO to address this request and to assess what management options were available to protect and maintain the forest resources on the ANF.

Project Location/Description

The Allegheny National Forest (ANF) is located in northwestern Pennsylvania. The forest extends into four counties; Elk (41˚29'N, -78˚51'W), Forest (41˚32'N, -79˚14'W), McKean (41˚47'N,-78˚49'W), and Warren (41˚43'N, -79˚8'W). The forest covers approximately 570,000 acres (Figure 1) of which 463,000 acres are forested. The ANF occupies the transition zone between the hemlock-white pine-northern hardwood and mixed mesophytic forest regions (Braun, 1950). The hemlock-northern hardwood forest type of pre-settlement times was composed mainly of eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*), and it has been replaced by the current mixed upland hardwoods and cherry-maple (Allegheny hardwood) types (Morin et al., 2006; Whitney, 1990). Currently, black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) are the most abundant species in the ANF (Morin et al., 2006). The mixed mesophytic forest is characterized by mixed species composition, including American beech (*Fagus grandifolia*), Tuliptree *(Liriodendreon tulipifera),* sugar maple *(Acer sacharum),* northern red oak *(Quercus rubra)* and white oak *(Q.*

alba). On the ANF, mixed oak forests occur within the mixed mesophytic forest portion of the forest along major drainages such as the Allegheny and Clarion River corridors, including around the Allegheny Reservoir. Mixed oak forest types occupy about 16% of the ANF (ANF LRMP).

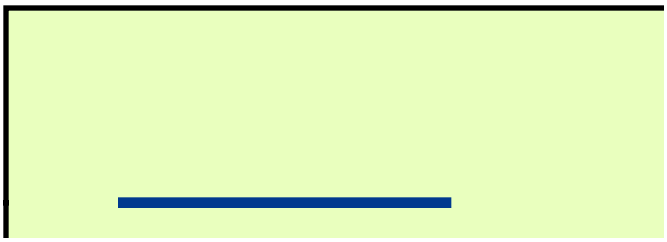

Figure 1. The four counties of the Allegheny National Forest in Northwestern Pennsylvania

Previous projects

The MFO has had a long relationship with the ANF, and has worked with forest staff on 7 different gypsy moth spray projects over the last thirty years. In total one-hundred and thirty seven thousand acres have been treated. The last major outbreak of the gypsy moth on the ANF occurred between 1991 and 1993.

Project Objectives

The objectives of this biological evaluation were to: 1) accurately assess current gypsy moth population densities within susceptible forest types on the ANF; 2) determine the likelihood of unacceptable impacts on forest resources occurring in the next growing season; and 3) develop

treatment alternatives and recommendations to suppress gypsy moth outbreaks likely to cause unacceptable impacts.

Project Methods

MODIS Satellite Data

We used a moderate resolution imaging spectroradiometer (MODIS) data to assess gypsy moth defoliation on the ANF. We acquired MODIS and normalized difference vegetation index (NDVI) data with a resolution of 250 m² (15.4-acre pixel) and 16-day interval composite data, from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET) online Forest Disturbance Mapper website (Figure 2). The data collected from this early warning systems uses the NDVI to measure and contrast the visible and near infrared spectral bands (Spruce et al., 2011). The NDVI relies on sensors aboard satellites to measure the absorption of red radiation by leaf pigments and chlorophyll and the scattering of the near infrared band by foliage to calculate a Healthy Green Foliage (HGF) value (Beck et al., 2006). The HGF value of each pixel is then compared to a 3-year historical baseline. Departures are then categorized into 4 classes based on the amount of change; 1) no change; 2) detectable; 3) moderate; and 4) severe.

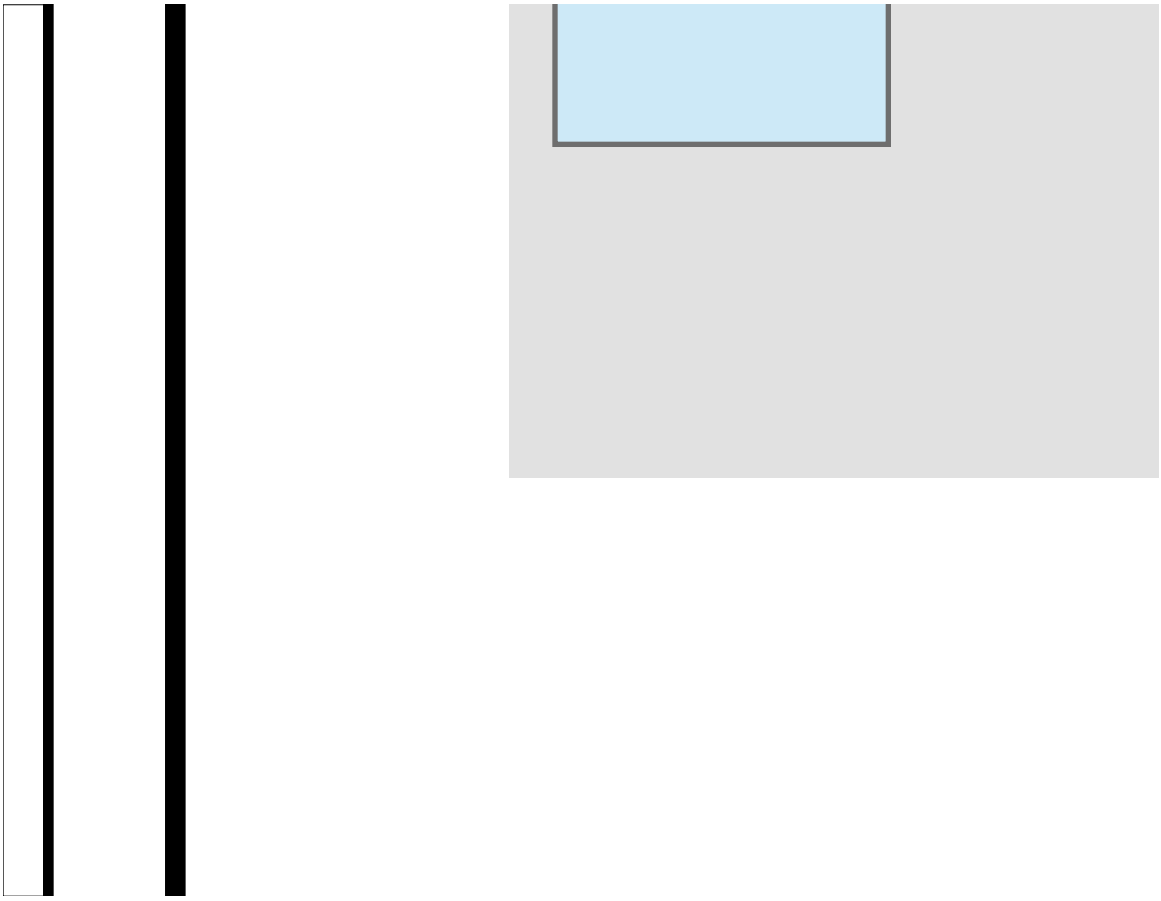

Figure 2. U.S. Forest Service Forest Health Technology Enterprise Team (FHTET) online Forest Disturbance Mapper data on gypsy moth defoliation on the Allegheny National Forest.

Survey Sites

To aid in directing surveys a composite map was created using ARCGIS®. Thematic maps representing, MODIS data, ANF management areas, ANF compartments and stands, ANF recreation areas, roads and trails, forest type, and oak basal area (Figure 4) were manually overlaid to create a composite map of susceptible forest types. This composite map was then reviewed by ANF and MFO staff and survey sites were selected (Figure 3).

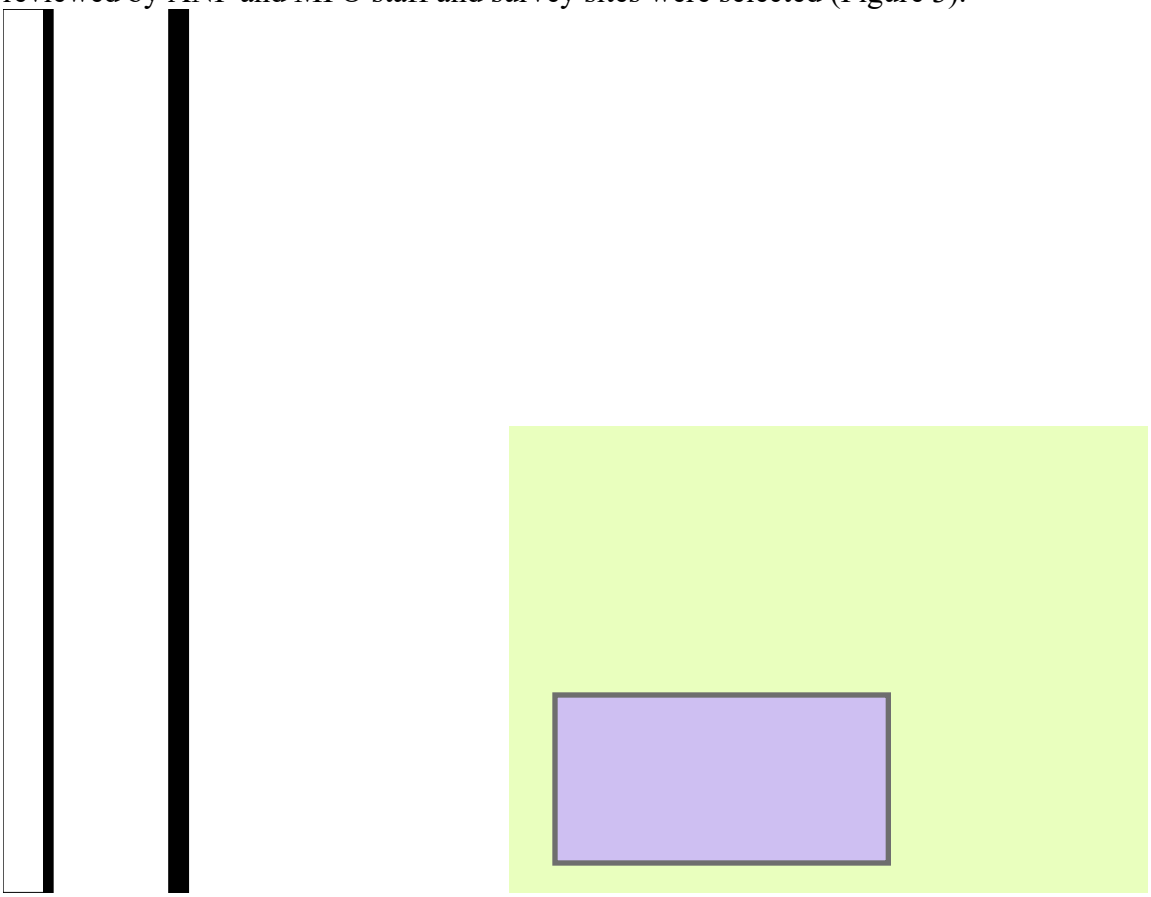

Figure 3. 2013 stand and gypsy moth survey locations on the Allegheny National Forest

Survey data

One-fortieth-acre circular plots (18.6-ft radius) were used to estimate egg mass densities within each selected area. At each sample point, a 1/40th acre fixed radius plot was established and the percent species composition and number of new and old egg masses were determined by inspection and visual count. An inspection of all egg masses within reach helped estimate the portion of new to old egg masses at each plot. Egg masses visual counts consisted of a tally of all egg masses observed on the overstory trees, understory vegetation, ground litter and duff. The total number of egg masses observed for each plot was summed and multiplied by the ratio of new egg masses to old egg masses (Liebhold et al. 1993) and multiplied by 40 to calculate the number of egg masses per acre. This was repeated for each plot and the results summed and averaged for a single density value for the area. In addition to density the standard error of the egg mass estimate was also determined to evaluate how much confidence could be placed on the

estimate. Three egg masses at each plot were also measured and averaged to provide additional information on condition and trend of the gypsy moth populations. Small egg masses (i.e. < 20 mm in length) are indicative of a declining population, while large egg masses (i.e. > 30 mm in length) of an increasing population (Liebhold et al. 1994).

Figure 4. Allegheny National Forest oak stands

Defoliation predictions

Defoliation predictions for 2014 within each area were based on the egg mass density, threshold, egg mass length, population trends and species composition (Liebhold et al. 1994, Liebhold et al. 1993; Table 1). Intervention thresholds for each area were established based on resource management objectives provided by the ANF and included nuisance abatement, and the prevention of defoliation.

Table 1. 2013 Gypsy moth egg mass density thresholds for resource management objectives on the Allegheny National Forest.

Threshold (egg masses/acres)	Predicted Defoliation	Objectives
250	< 30[1] %	Nuisance Abatement
251-500	30 - 40 % (Light)	Prevent Noticeable Defoliation
501-1000	41 - 60 % (Moderate)	Prevent Growth Loss
>1000	> 60 % (Heavy)	Prevent Mortality

[1] None or background level of defoliation.

Results

Acres Defoliation

An assessment of the MODIS satellite data showed that peak disturbance occurred between June 10 and 25, 2013. During this period approximately 105,000 acres of detectable departure from the 3-year historical baseline was detected (Figure 2). Field reports from ANF staff reported high levels of defoliation across the ANF, with numerous reports of complete defoliation coming from areas around the Allegheny Reservoir and Kinzua Dam. As a result of this high level of defoliation most trees in these areas refoliated, and field reports by ANF personnel from mid-late summer reported nearly complete recovery of the canopies in most areas.

Figure 5. Gypsy moth larva cadavers on bole of oak.

Defoliation Predictions

In total one-hundred-ninety one plots (Figure 3) at thirty-five survey areas were assessed during the fall of 2013. Gypsy moth population densities in each area are summarized in Table 4. Species composition was a mix of preferred and less preferred species consisting of northern red oak (*Quercus rubra*), white oak (*Q. alba*), Chestnut oak (*Q.prinus*), red maple (*Acer rubrum*), black cherry (*Prunus serotina)*, black birch (*Betula lenta*), yellow birch (*B. alleghaniensis*), American hornbeam (*Carpinus caroliniana*), yellow popular (*Liriodendron tulipifera*) and eastern hemlock (*Tsuga canadensis*). Overall, average egg mass densities ranged from 0-1,020 egg masses/acre. Egg mass lengths tended to be large in size, ranging from 9-50 mm and an

average of 33 mm. Three of the survey areas, Cornplanter Bay, Hodge Bay and Hopewell campground (Table 4) contain egg mass densities sufficient to predict moderate to heavy defoliation (> 41%) for 2014. Light defoliation is predicted at Sugar Bay and Central Hodge Bay (Table 4) with the remaining areas having egg mass densities sufficient to predict background or nuisance levels of gypsy moth defoliation.

Gypsy moth fungus

Field surveys and field reports noted large numbers of gypsy moth larva cadavers on the boles of trees throughout the ANF (Figure 5). These cadavers were hanging vertically with the prolegs extended which is consistent with *Entomophaga maimaiga* infection, a fungal pathogen of the gypsy moth (Hajek and Snyder, 1992). This pathogen can cause epizootics which can lead to substantial gypsy moth mortality (Hajek, 1997). Based on the results of the surveys and field reports it appears that an epizootic caused by the gypsy moth fungus occurred at most areas surveyed.

Discussion

Predicting the extent of impact of gypsy moth on individual trees or areas is uncertain and highly variable egg mass counts were found at nearly every area (Table 4). Gypsy moth population trends appear to have been increasing (Figure 2; Table 4) with no defoliation noted in 2012 to nearly 105,000 acres of defoliation in 2013. Field observations by ANF staff revealed that in many areas trees re-foliated because of gypsy moth defoliation. Since defoliation reduces the trees ability for future photosynthesis and re-foliation events causes the tree to expend carbohydrate reserves, it is these factors that must be considered when deciding whether intervention is necessary or warranted. Other factors that need to be considered are the condition of the trees at the time of defoliation (i.e. stand stocking, age and amount of susceptible species present). Studies have shown (Gottschalk 1989), that reduced growth, mast abortion, branch dieback or in some cases tree mortality, has been observed following a single year of heavy defoliation. Should a subsequent period of drought or other stressors occur during a defoliation event or even after, the potential impact on individual trees may be compounded.

The natural control factors operating in the survey areas were not quantitatively surveyed, but observations indicate that the gypsy moth fungus, *E. maimaiga* was active. It is likely this fungus adversely influenced gypsy moth infestations on the ANF in 2013 and this could be repeated if there is a wet spring in 2014. The gypsy moth nucleopolyhedral virus (NPV) was also observed, but this pathogen operates at high larval densities and does not kill as quickly as the fungus, so its effects are usually masked by the presence of the fungus.

Table 4. Gypsy moth egg mass survey results, thresholds and predicted defoliation for the Allegheny National Forest.

Area	Survey Site	2013 Egg Mass /acre	Standard Deviation	2014 Predicted Defoliation (%)
1	Jakes Rocks	205	312	< 30
2	North Country Trail	0	0	0
3	Rimrock	127	310	< 30
4	Tracy Ridge	0	0	0
5	FS 201	0	0	0
6	North Country Trail	0	0	0
7	Morrison Trail	0	0	0
8	Sugar Bay	373	647	30 - 40
9	Willow Creek ATV Trail	0	0	0
10	Hook Brook CG	91	108	< 30
11	Hopewell CG	625	269	41 - 60
12	Camp Olmstead	60	104	< 30
13	Handsome Lake CG	0	0	0
14	Cornplanter Bay	688	960	41 - 60
15	Hodge Bay	1020	1865	> 60
16	Rimrock Trail	127	120	< 30
17	Willow Bay	50	50	< 30
18	Webbs Ferry	0	0	0
19	Jamison Run	74	105	< 30
20	FR 489	80	139	< 30
21	Dawson Run	0	0	0
22	Pigeon Hill Rd	10	20	< 30
23	Route 666	8	18	< 30
24	FR 159	0	0	0
25	Tanbark Trail	0	0	0
26	Hearts Content Rd	0	0	0
27	Pigeon Hill Rd	200	346	< 30
28	FR 362	10	20	< 30
29	Rocky Gap ATV Trail	120	268	< 30
30	Tracy Ridge	0	0	0
31	Tracy Ridge/North Country Tr.	13	33	< 30
32	Kinzua Heights	0	0	0
33	Hemlock Run	19	62	< 30
34	Central Hodge Bay	388	322	30 - 40
35	FR 160	33	82	< 30

Management Options

For 2014, two management options have been evaluated based on decisions by the ANF for managing gypsy moth populations. The intervention option is offered based upon the following three treatment objectives: 1) for nuisance abatement of gypsy moth population in high value camping and recreation areas and 2) protect host tree foliage to prevent branch dieback and tree mortality. Each option is discussed below.

No Action option

It is possible that gypsy moth populations could naturally collapse due to the presence of the gypsy moth NPV or the gypsy moth fungus, *E. maimaiga.* Where defoliating gypsy moth populations are greater than 500 egg masses/acre, viral epizootics generally manifest themselves only after significant tree defoliation has already occurred. Gypsy moth populations will usually peak in two-three years once they reach defoliating levels and then collapse because of NPV or fungal activity. Residual populations following such a collapse will likely remain at low densities for three-six years before rebuilding to defoliating levels.

Should this option be selected for 2014, it is likely that some localized defoliation will occur. There is also the potential for population densities to increase in infested stands and expand to currently uninfested areas in 2015.

Microbial insecticide option

The second option is to use microbial insecticides to manage gypsy moth populations. Two biological insecticides are currently registered and commercially available for gypsy moth control. One is the microbial insecticide, *Bacillus thuringiensis* variety *kurstaki (B.t.k).* *B.t.k.* is a bacterium that acts specifically against lepidopterous larvae as a stomach poison and therefore must be ingested. The major mode of action is by mid-gut paralysis, which occurs soon after feeding. This results in a cessation of feeding, and death by starvation. *B.t.k.* has been shown to impact other non-target caterpillars that are exposed to the treatment when actively feeding. *B.t.k.* is persistent on foliage for about 7-10 days.

B.t.k is not specific and may reduce populations of short term non-target lepidoptera larvae that may be feeding at the same time as gypsy moth caterpillars. Several factors must be taken into account when using *B.t.k* such as: 1) the potential for short term non-target extirpation in the proposed spray area; 2) the life stage present and any deferential susceptibility to *B.t.k* that may exist between species of non-target lepidoptera; 3) the size and uniqueness of the area beginning

proposed for treatment. Since much of this site-specific data regarding non-target lepidoptera may not be known for many areas, the potential benefits must be weighed against any potential impacts to non-targets.

B.t.k. formulations are available as a flowable concentrate. The normal application rates range from 24-38 Cabbage Looper Units (CLU's) per acre in a single application for a total volume of ½ to ¾ gallon per acre. Double applications may be used in areas of healthy building populations where the egg mass densities may exceed 3,000 egg masses per acre. With proper application, foliage protection and some degree of population reduction can be expected with one application. Because *B.t.k.* is a biological insecticide, the degree of population reduction varies and may depend on, at least in part, the selected application rate, relative health of the population (building vs. declining), population densities, weather (rain and temperature), the feeding activity of the larvae following treatment, and the actual potency of the product (CLU's).

The second microbial insecticide that is registered and available in limited quantities is the formulated nucleopolyhedrosis virus called Gypchek® (U.S. Forest Service, USDA, Washington, DC). This product is not available commercially but is produced in limited quantities by a cooperative effort of the USDA Forest Service and the Animal Plant Health Inspection Service (APHIS). The active ingredient in Gypchek formulations has a very narrow host range (lymantriids) and occurs naturally in gypsy moth populations. Normally the virus reaches epizootic proportions when gypsy moth populations reach high densities as a result of increased transmission within and between gypsy moth generations. The application of Gypchek to gypsy moth populations simply expedites this process by increasing the exposure of the virus at an earlier stage. Healthy, feeding gypsy moth caterpillars become infected by ingesting contaminated foliage and soon stop feeding and die.

The efficacy of Gypchek treatments to reduce gypsy moth populations has been quite variable. Because of the short period of viral activity on foliage (3-5 days) as well as other biological factors such as feeding activity and weather conditions, it has been difficult at best to project treatment efficacy. Most often foliage protection can be achieved but significant reductions in gypsy moth densities do not always occur. Should inadequate population reduction occur, areas would need to be treated again the following year. The normal application rate of Gypchek is $4x10^{11}$ occlusion bodies (OB's) per acre applied once.

With the previously described options in mind, the following alternatives are offered.

Alternatives

Alternative 1 -No action

Alternative 2	-One aerial application of *B.t.k.* at the rate of 24-38 BIU/acre for all proposed spray areas.

Recommendations

For 2014, it is recommended that the ANF decide in favor of alternative one. At this time the no action option seems the most appropriate action. High levels of larval mortality and low egg mass densities at the majority of sites indicate that gypsy moth population in most areas have been reduced and/or collapsed. We acknowledge that there is some uncertainty in our projections, but our estimates currently only predict localized moderate to heavy defoliation in three small localized areas: Cornplanter Bay, Hodge Bay and Hopewell campground areas. The remaining survey areas across the ANF have egg mass densities sufficient to predict background or nuisance levels so a widespread defoliation event is not expected. Based on these results a gypsy moth a treatment project is not recommended for the Allegheny National Forest in 2014, however, continued monitoring of areas defoliated in 2013 and susceptible forest types is recommended.

Species Evaluation

The gypsy moth, *Lymantria dispar* (Linneaus) is a non-native defoliator of forest, shade and ornamental trees throughout the Northeastern United States. Since its intentional importation and accidental release in eastern Massachusetts in 1869, the gypsy moth has steadily expanded its range.

The gypsy moth produces one generation per year. Larvae begin hatching from egg masses in late April and early May when tree buds begin to open. At this time, larvae go through an obligatory dispersal period where they leave the vicinity of the egg, moving upward and spinning a thread of silk as they go (Leonard 1981). Eventually the wind catches the larvae and disperses them. Airborne larvae are carried and deposited some distance downwind from the source with the following results: 1) larvae will land on or crawl onto acceptable host plants and begin feeding; 2) larvae will land on either acceptable or unacceptable host plants and re-disperse; 3) larvae will be deposited into areas unacceptable for survival and re-dispersal where they will die (Mason and McManus 1981). The larvae feed for two to three months completing their development by late June and early July and seek sheltered areas in which to pupate. The pupal period can last anywhere from 10 days to two weeks. After emerging from the pupal case the females, which cannot fly, crawl a short distance and emit a pheromone scent to attract males. After mating, the female lays a single egg mass that contains from 75 to 1,000 eggs, which she covers with hairs from her abdomen giving it a fuzzy brown texture and color. The egg masses over winter and hatch the following spring.

The number of host trees and shrubs fed on by the gypsy moth exceeds 300 species, with species of oaks (*Quercus* spp.) ranked among the most favored (Leonard 1981).

Favored Tree Species – The following is a listing of common tree species arranged by gypsy moth feeding preference:

- **Favored – High:** Fed upon by all size larvae – alder, apple, aspen, basswood, beech, birches (gray, white, and river), boxelder, hawthorn, larch, oaks (all species), willows, and witchhazel.

- **Favored – Moderate:** Fed upon by only large larvae – chestnut, eastern hemlock, and all species of pine and spruce.

- **Favored – Low:** Only fed upon by large larvae when preferred foliage is not available – birches (black and yellow), butternut, cherry, cottonwood, elms, gum (black), hackberry, hickories, hornbeam, maples, pear, sassafras, sweetgum, and walnut.

- **Unfavored:** Rarely fed upon – ashes (all species), catalpa, dogwood, holly (American), honey locust, horsechestnut, juniper, locust, maple (striped), mulberry, persimmon, red cedar (eastern), sycamore, and tulip poplar.

Gypsy moth is an outbreak species whose populations can remain at low levels for several years, then undergo large population increases in a matter of one or two years. After populations have increased to an outbreak density they can remain high for one to five years, outbreaks decline suddenly to low densities where it is difficult to find any life stage (Liebhold et al. 2000). The main effects of gypsy moth feeding on individual trees involves the depletion of root carbohydrate food resources leading to a reduction in growth, reproduction, and increased vulnerability to secondary agents of mortality. Heavy defoliation forces re-foliation which occurs when about 60 percent of the foliage is lost (Liebhold et al. 1994). This re-foliation uses carbohydrate reserves in trees and can increase their vulnerability to drought and to other insects and diseases. This defoliation and subsequent tree mortality can alter wildlife habitats, change water quality and temperature, increase forest floor temperatures and light levels and reduces aesthetic, recreational, and property values of forests and urban environments.

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